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(54) QUALITY OF SERVICE SCHEDULING SCHEME FOR A BROADBAND WIRELESS ACCESS SYSTEM

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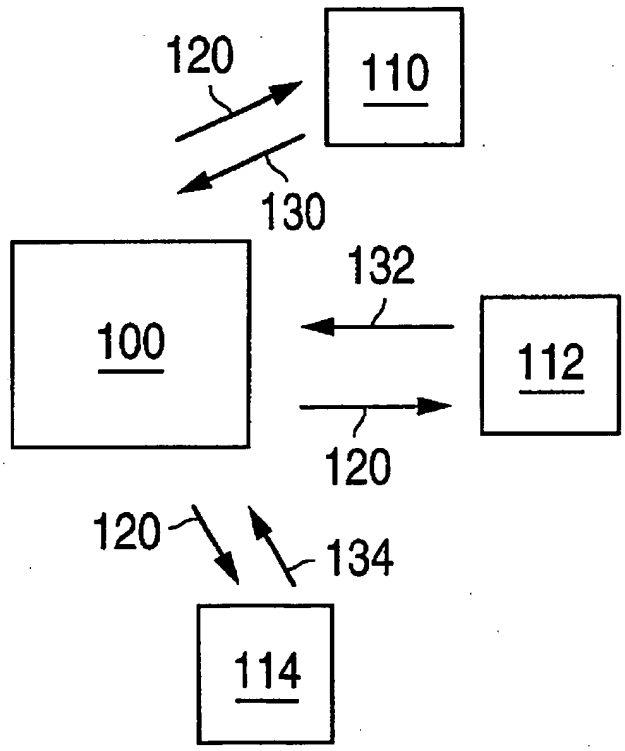
(57) ABSTRACT

A dynamic quality of service maintenance system for use with a broadband wireless or cable access system comprising a plurality of wireless modems and a wireless hub, the dynamic quality of service maintenance system maintaining adequate bandwidth for the wireless modems based upon the services provided to the wireless modems by the broadband wireless access system.



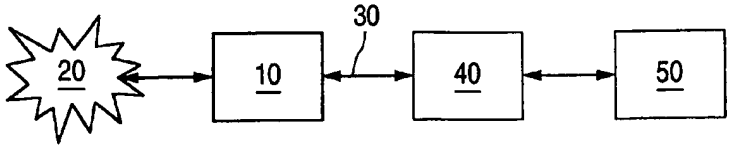


Fig. 1

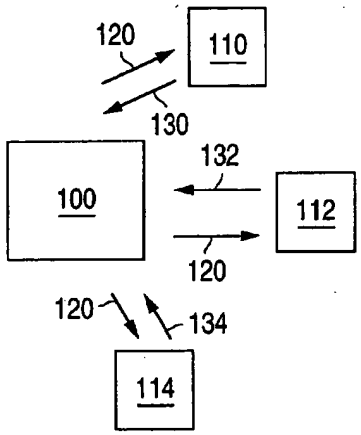


Fig. 2

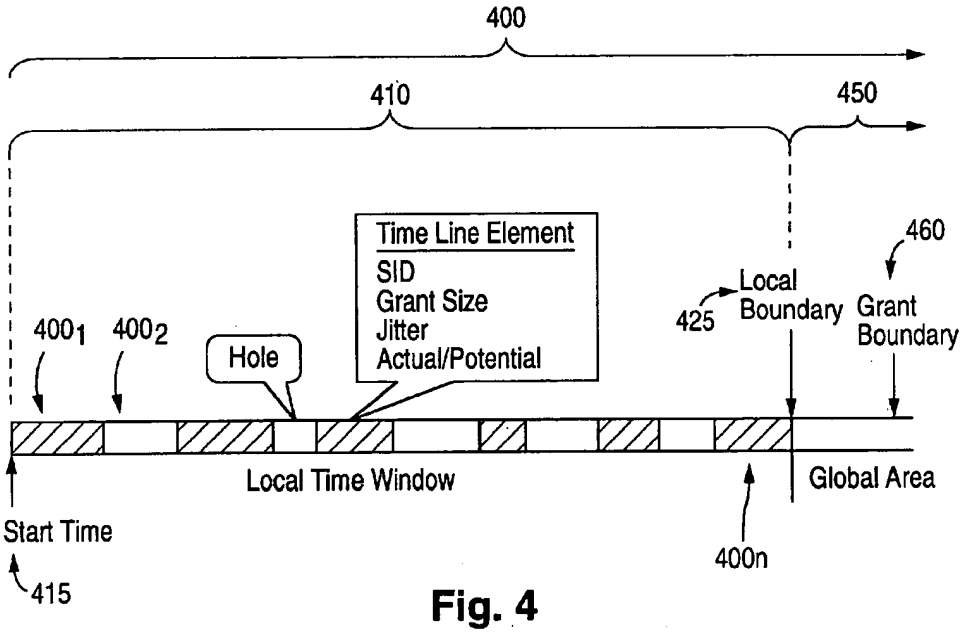


Fig. 4

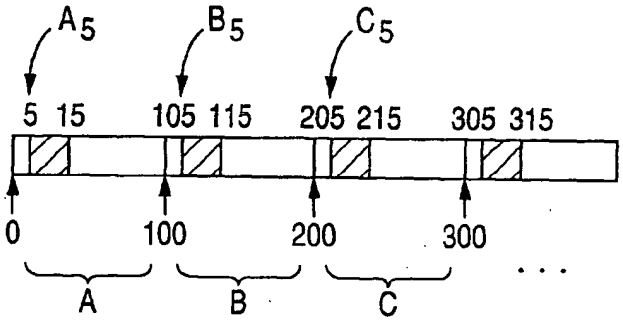


Fig. 3

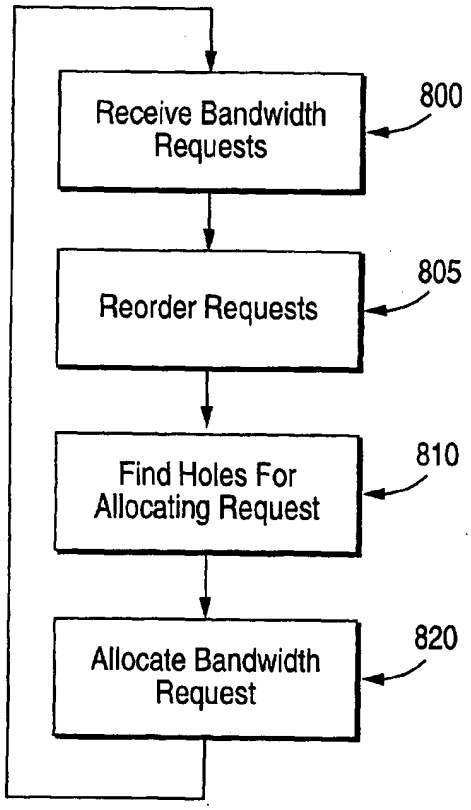


Fig. 8

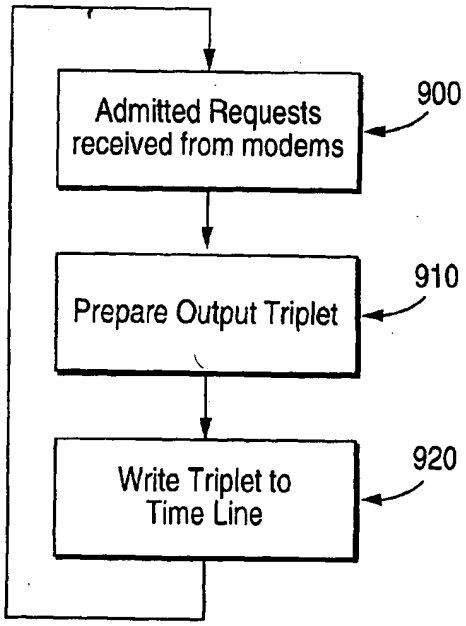


Fig. 9

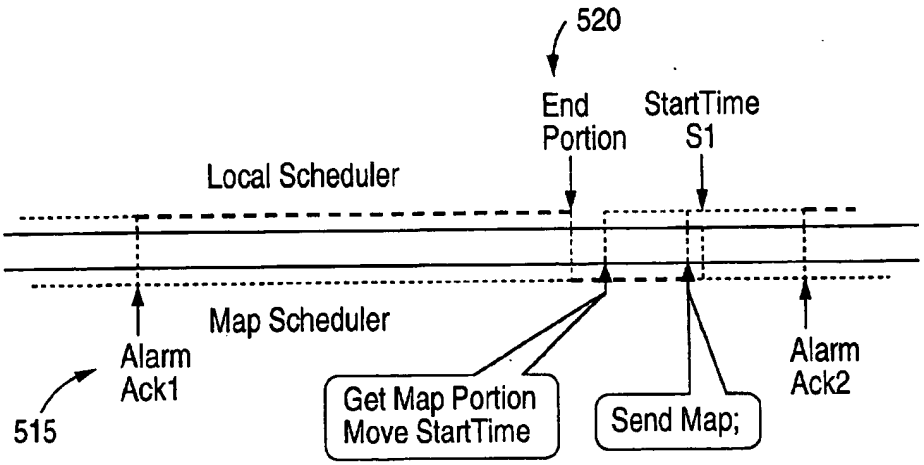

520
End Portion
StartTime S1
Local Scheduler
Map Scheduler
Alarm Ack1
515
Get Map Portion Move StartTime
Send Map;
Alarm Ack2

Fig. 5

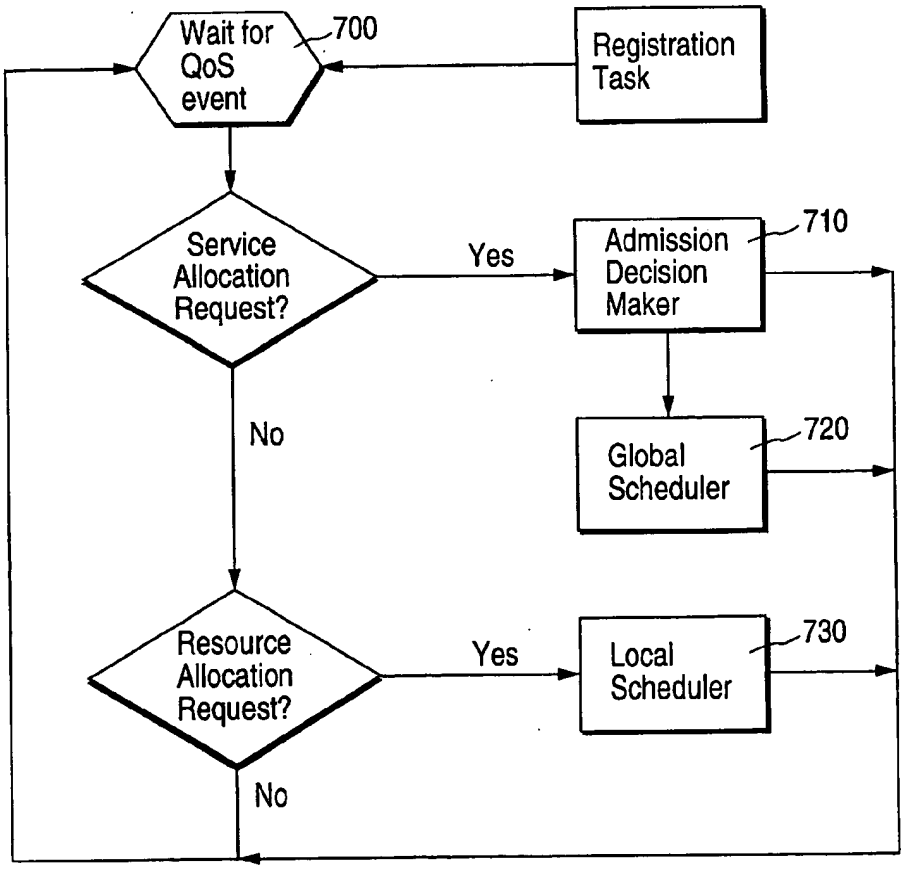

Wait for QoS event
700
Registration Task
Service Allocation Request?
Yes
Admission Decision Maker
710
No
Global Scheduler
720
Resource Allocation Request?
Yes
Local Scheduler
730
No

Fig. 7

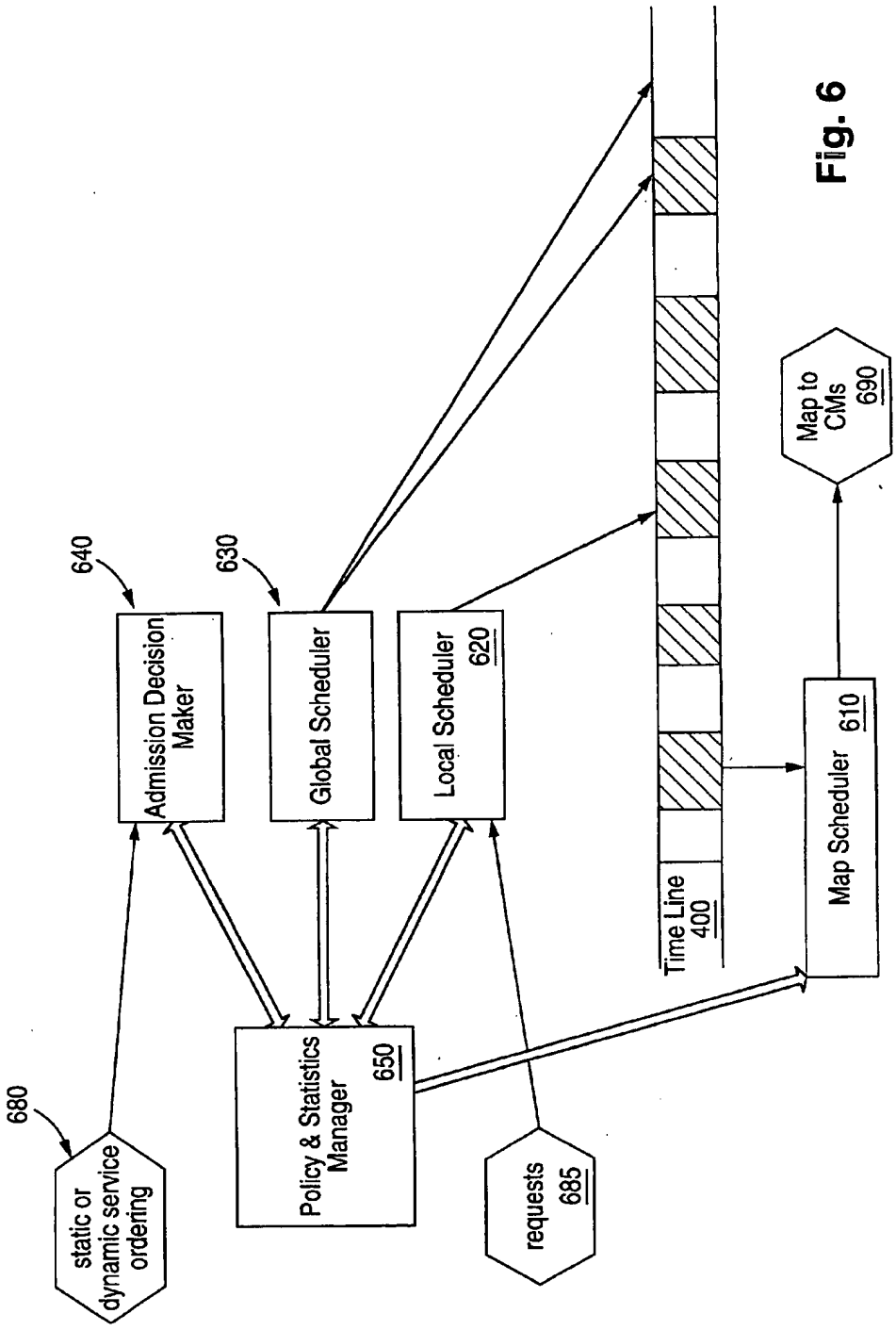

Map to CMs 690
640
630
Admission Decision Maker
Global Scheduler
Local Scheduler 620
Time Line 400
Map Scheduler 610
680
static or dynamic service ordering
Policy & Statistics Manager 650
requests 685

Fig. 6

QUALITY OF SERVICE SCHEDULING SCHEME FOR A BROADBAND WIRELESS ACCESS SYSTEM

BACKGROUND OF THE INVENTION

[0001] 1. Field of Invention

[0002] The present invention relates to broadband wireless access systems and amongst other things to a method of dynamic maintenance of quality of service in a broadband wireless access system.

[0003] 2. Discussion of Background

[0004] Point to multi-point fixed broadband wireless access systems over MMDS networks are known in broadcast situations. These networks operate over licensed bands including the MMDS band (2,150 to 2,162 MHz), the WCS band (2,305 to 2,360 MHz) and the ITFS/MMDS bands (2,500 to 2,686 MHz).

[0005] A known cable based broadband access system, which operates at a range of between 50 MHz and 864 MHz, but not in the MMDS, WCS, or ITFS/MMDS bands, is the data over cable specification system, which is specified in the data over cable system interface specifications (DOCSIS). An overview of a cable based DOCSIS system is depicted in **FIG. 1**. A CMTS **10** communicates with a wide area network **20**, such as the internet. The CMTS **10** can transmit signals from the wide area network **20** along a cable network **30** through cable modems **40** to CPE **50** (Customer Premise Equipment—intended throughout this document to include a computer and/or all of the equipment at the customer site, such as a LAN—Local Area Network). CPE **50** messages can be transmitted to the wide area network **20** through the cable modem **40** along the cable network **30** to the CMTS **10**.

[0006] In point to multi-point broadband access systems one central end-point, e.g. the head-end, communicates through a bi-directional link or links with multiple end-points, e.g. the nodes. The number of nodes in communication varies in time and can be none, one or two or more at any specific time.

[0007] The link(s) between the head-end and the nodes are combined in one or more channels. The signal path from the central end-point to the nodes is referred to as downstream, while the signal path from the nodes to the central end-point is referred to as upstream.

[0008] A single upstream channel can be used to deliver information from a node to the head-end, and a downstream channel is used from the head-end to a node or a group of nodes. If a single upstream channel is used for communication from the nodes(s) to the central point, then only one end-point can sends information on the single upstream channel at any one time.

[0009] A known allocation scheme, for scheduling upstream channels and mini-slots in the channels, is referred to as contention-based allocation. This allocation scheme allows more than a single node to use the same time interval. In such allocation an allocation scheme, there is some probability that more than one node will try to send information on the same upstream channel at the same time. In this case, the information from all or some of the nodes transmitting messages on the same upstream channel at the same time will not be received at the central end-point. These nodes, from which the message is not received, will retransmit the same message until such a time when the central end-point receives that transmission. Further, during the time when it is re-transmitting the same message, the node cannot transmit new messages.

[0010] Another known upstream channel allocation scheme is defined DOCSIS. These specifications refer to the case of HFC network. In the DOCSIS system, each upstream channel is assigned a different frequency range. Different channels are used for upstream or downstream directions.

[0011] In the DOCSIS scheme there is no need to coordinate the downstream channel, since only the head-end is transmitting in this direction. Further in DOCSIS, the head-end is responsible for the allocation of the upstream channels. These allocations are performed in two general steps, one for the allocation of an upstream channel and the other for the allocation of time intervals in the upstream channels.

[0012] The allocation of the time intervals on each upstream channel is also performed by the head-end. The head-end transmits the time interval allocations on the downstream channel in a message called MAP. A single MAP message describes time interval allocation on a single upstream channel for a specific period of time.

[0013] The DOCSIS solution uses a fixed upstream channel for each node, which implies that statistical changes to the traffic load may cause a high load on one channel, while not allowing other channels with lower loads to be used to balance higher load channel. Further, if the performance of the current upstream channel of a node becomes unacceptable, e.g. falls below predetermined threshold levels, the node must switch to an alternate channel. This switching process, which includes a search for the best available channel, takes a longtime during which service to the node is interrupted.

[0014] When multiple services are supported by the broadband access system, some Quality of Service (QoS) requirements need to be defined which add additional limitations on any allocation scheme or scheduling scheme. The services may include voice IP, broadband video on demand or other services that may require different downstream and upstream bandwidth, with respect to the modem, than the standard IP traffic that comprises Internet communication.

[0015] Therefore, it is necessary to schedule upstream communication based upon the specific requirements of each service that is being utilized by the user.

SUMMARY OF THE INVENTION

[0016] The present invention provides a method and system for scheduling and allocating the appropriate bandwidth to a plurality of user devices in such a way as to assure adequate bandwidth regardless of the type of service utilized by the user device.

[0017] In another embodiment, a scheduler for use broadband wireless access system comprising a plurality of wireless modems and a wireless hub, maintains adequate bandwidth for the wireless modems based upon the services provided to the wireless modems by the broad band wireless access system.

[0018] The present invention is embodied as a wireless communication system, comprising, a wireless hub configured to send downstream communications on at least one downstream channel and receive upstream communications from at least one client device on at least one upstream channel, wherein said wireless hub comprises, a timeline, having timed storage allocations for scheduled services to be provided in conjunction with at least one client device that is communicating with said wireless hub, a scheduling mechanism configured to, receive service requests from said client devices, determine available time for provision of the requested service, and place a marker identifying the requesting client and the service to be provided in a timed storage location of said timeline corresponding to the available time, and a map scheduler configured to retrieve markers in a time window of said timeline and build a MAP message that describes time interval allocation on an upstream channel for said time window.

[0019] The present invention includes a method of service scheduling of an upstream channel in a point to multi-point communication system, wherein said point is a hub device, and said multi-point is a set of client devices communicating with said hub, comprising the steps of, scheduling said services in a timeline so as to identify a client device, building a MAP message comprising at least a portion of the services scheduled in said timeline, and communicating said timeline to said client devices.

[0020] Both the device and method may be conveniently implemented on a general purpose computer, or networked computers, and the results may be displayed on an output device connected to any of the general purpose, networked computers, or transmitted to a remote device for output or display.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] A more complete appreciation of the invention and many of the attendant advantages thereof will be readily obtained as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings, wherein:

[0022] **FIG. 1** is an overview of a known wireless data over cable system;

[0023] **FIG. 2** is a block diagram of a wireless hub communicating with a plurality of wireless modems in a broadband wireless access system according to a presently preferred embodiment of the present invention;

[0024] **FIG. 3** is a diagram of an allocation in a global area of a time line according to a presently preferred embodiment of the present invention;

[0025] **FIG. 4** is a diagram of time line with a local time window and global area according to a presently preferred embodiment of the present invention;

[0026] **FIG. 5** is a diagram of the interaction of local scheduler and map scheduler according to a presently preferred embodiment of the present invention;

[0027] **FIG. 6** is a flow chart illustrating processes and data flow in an embodiment of the present invention;

[0028] **FIG. 7** is a flow chart illustrating a service/bandwidth request processing loop according to an embodiment of the present invention;

[0029] **FIG. 8** is a flow chart illustrating a high level view of Local Scheduling according to an embodiment of the present invention; and

[0030] **FIG. 9** is a flow chart of the Global Scheduling process according to an embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0031] Referring again to the drawings, wherein like reference numerals designate identical or corresponding parts, and more particularly to **FIG. 2** thereof, there is illustrated [. . .].

[0032] Referring to **FIG. 2**, in the presently preferred embodiment, a wireless hub communicates with a number of wireless modems **110, 112** and **114** on downstream channel **120** and upstream channels **130, 132** and **134** respectively. The wireless hub by determining the load and other performance characteristics of each upstream channel **130, 132** and **134** can assign in the next allocation MAP any of the wireless modems **110, 112** or **114** to another upstream channel of a group of upstream channels assigned by the wireless hub to the wireless modem **110, 112** or **114**. This can be an assignment of one of the wireless modems to a same upstream channel as another wireless modem, e.g. assigning wireless modem **110** to upstream channel **132**, or assignment to a completely different upstream channel, e.g. assigning wireless modem **112** to upstream channel **136** (not shown). Each of the wireless modems utilizes some of a plurality of different services provided by the wireless hub. Such services include video and voice IP.

[0033] Turning now to **FIG. 6**, there is illustrated a Quality of Service architecture **600** consistent with an embodiment of the present invention.

[0034] The QoS Architecture **600** includes five architectural levels: (1) Map Scheduler **610**; (2) Local Scheduler **620**; (3) Global Scheduler **630**; (4) Admission Decision Maker **640**; and (5) Policy & Statistics Manager **650**.

[0035] The following table shows the presently preferred main data structures used in the inventive scheduling method and system:

Name	Comments	Access
Time Line	the sequence of Time Line Elements ordered by time	Map Scheduler - r/o Local & Global Scheduler - r/w
Bandwidth Requests	As defined by DOCSIS	Map Scheduler - n/a Local Scheduler - r/o Global Scheduler - n/a
Maps Ack Requests	As defined by DOCSIS	Map Scheduler - r/w Local Scheduler - n/a Global Scheduler - n/a
Services Description	Set of parameters based upon DOCSIS definitions	Map Scheduler - n/a Local Scheduler - r/o Global Scheduler - r/w

Legend:
r/o - read only,
r/w - read and write, and
n/a - no access.

[0036] It should be noted that the present invention can operate as long each of the pieces of information discussed

is provided and utilized appropriately, and is not limited to the specific data structures or names utilized.

[0037] The Map Scheduler **610** is a mechanism that constructs map messages in accordance with the Data Over Cable System Interface Specification (DOCSIS) Radio Frequency Specification, SP-RFIvv1.1-I03-991105, standard which are then sent out, which is incorporated herein in its entirety by reference as if fully set forth herein.

[0038] Further DOCSIS scheduling information is discussed in DOCSIS Specification #SP-OSSI-I03-990113, which is also incorporated herein by reference as if fully set forth herein in its entirety.

[0039] The Map Scheduler **610** is not provided information regarding incoming bandwidth requests by the wireless modems (or CMS). It operates on the basis of information retrieved from a Time Line **400**, into which the higher scheduler levels may have placed grants. It also takes into account the Ack Requests queue. The Map Scheduler sets actual Map sizes and the time of sending a Map Message to the wireless modem(s) (or cable modems, CMs, etc.) in accordance with a given policy. That policy is maintained or determined by the Policy and Statistics Manager **650**.

[0040] As illustrated in **FIG. 5**, the Map Scheduler **610** operates in conjunction with the Time Line **400** when an alarm occurs. For example, when an alarm **515** occurs, the Map Scheduler starts functioning by reading the Ack Time Register (this switches the banks of acknowledgement requests and bandwidth requests) and inserts it and the acknowledgements into the Map Message. It then extracts a portion of elements from the Time Line [from a start time **415** to end portion **520**], shifts the Start Time pointer **415**, and proceeds with the construction of the Map Message. (It also processes the Local and Grant Boundary pointers—see below regarding the Time Line Implementation).

[0041] When constructing the map, the Map Scheduler inserts "pending" for all grants allocated in the Time Line and not included in the current map. A supplementary table, referred herein as the Grant Time Table, is preferably used for that purpose.

[0042] The timeline is constructed in a service/bandwidth request processing loop. Illustrated in **FIG. 7** the service/bandwidth request processing loop beings in a wait state **700** for a QoS (Quality of Service) event, such as a request from a modem. If the request is a service allocation request, the Admission Decision Maker **640** either admits or rejects the request. If admitted, the request is sent to the Global Scheduler **630** for inclusion on the Time Line. If the request is a resource allocation request, it is forwarded to the Local Scheduler **620** for allocation on the timeline.

[0043] The Local Scheduler **620** processes incoming bandwidth requests and generates data grants in accordance with the Service, registered for the requesting SID (Station ID). The Local Scheduler **620** does not operate in terms of maps, its purpose is to place data grants into the Time Line, to be ready for assignment by the Map Scheduler.

[0044] The Local Scheduler **620** is the most responsive to real-time processes and requests. It preferably must guarantee the appropriate processing of all incoming requests. Enforcement is described below with respect to Grant Provisioning.

[0045] When making decisions on providing grants, the Local Scheduler **620** utilizes algorithms necessary to model the services supported, e.g. the video or Voice IP services. The modeling parameters of the service are set at the Global Scheduler level when the Service has been admitted for the SID in question. For example, a Token Bucket scheme works at this level. Also, if a Fragmentation Mechanism is not implemented, when issuing a data grant, the Local Scheduler finds a non-occupied segment of the Time Line, a "hole", in a most optimal way.

[0046] **FIG. 8** illustrates a flow chart of basic Local Scheduling according to an embodiment of the present invention. At step **800**, a bandwidth or other resource allocation request is received. At step **805**, the received bandwidth requests are ordered based on service parameters. Any ordering algorithm may be utilized, such as the fair-rate queuing algorithms discussed below. The local scheduler then takes the request having the highest priority and finds a suitable hole or holes (empty mini-slots) in the local time window to service the high priority request (step **810**), and allocates them into the holes of available mini-slots in the timeline (step **820**). Bandwidth requests are preferably allocated from empty mini-slots (holes) within the Local Time Window, however, requests may be allocated before the Grant Boundary **460**.

[0047] The main function of the Global Scheduler **630** is to provide preliminary global time scheduling for SIDs according to the admitted Static and Dynamic Services by marking the Time Line with periodic potential or actual Time Line Elements (grants). This marking is carried out on the basis of the admitted services' parameters. **FIG. 9** illustrates a high level flow chart of the Global Scheduling process according to an embodiment of the present invention. At step **900**, admitted service allocation requests are received by the Global Scheduler **630**. The Global Scheduler prepares an output triplet reflecting the parameters of the admitted service (step **910**), and the triplet is written to the Time Line (step **920**).

[0048] It is also the responsibility of the Global Scheduler **630** to manage the grant of periodic ranging request opportunities. This is done by placing grants into the Time Line, including the Global Area.

[0049] The Global Scheduler **630** provides bandwidth allocation for SIDs in the Time Line, in both the Local Time Window and the Global Area. This is done for admitted Services.

[0050] The Admission Decision Maker **640** processes incoming requests for Static and Dynamic Service ordered by the wireless modems. This Quality of Service scheduling architectural level is responsible for processing of such requests in accordance with the DOCSIS standard. The decision is made by analyzing the Model while attempting to incorporate specific Resource Estimations obtained from the Policy Architectural Level into the Model. When a Service is admitted, the Global Scheduler fills out Service Description data.

[0051] For both Static or Dynamic Service ordering, resource consumption is forecasted and estimated. This is the responsibility of the Policy Level (Policy & Statistics Manager **650**). Resource estimation is provided on the base of information on the type of the application, running on the remote PC, history of processing, if available, statistics, etc.

[0052] Two important examples of services that require Resource Estimation are the Unsolicited Data Grant with Activity Detection and the Best Effort services.

[0053] The Admission Decision Maker **640** component checks whether it is possible to include the new service together with its Resource Estimation into the Admission Resource Model. The Admission Resource Model is represented by the Time Line (its Global Area only) in the same way as is done for the Global Scheduler. The Admission Decision Maker **640** provides periodic comparison of the real life Time Line allocation with that of the Admission Resource Model. If the actual behavior of a SID does not correspond to the Admission Resource Model forecast, then a correction of the Model is made. This correction is passed over to the Policy Level.

[0054] For example, consider a SID ordered for Unsolicited Data Grant with Activity Detection. The Policy Level analyzes the nature of this SID on the basis of available statistics. It then forecasts its activity behavior. The output of this stage is an Estimated Resource, represented in the form of a periodic triplet. This Estimated Resource is recommended to be used by the Admission Decision Maker.

[0055] The Admission Decision Maker periodically compares the Model with the real Time Line Allocation. For example, it sees, that our SID consistently overflows the Estimated Resource previewed by the Model. This means that the analysis by the Policy Level has been incomplete and needs correction.

[0056] DOCSIS Implementation

[0057] Unsolicited Grant Service

[0058] The parameters used in the presently preferred unsolicited grant Service are the same as those used in the DOCSIS specification.

[0059] The Global Scheduler Level generates a (periodic) actual grant triplet in accordance with the service parameters and invokes the Global Time Line Allocation routine.

[0060] Best Effort Implementation

[0061] The parameters used in the presently preferred best effort implementation are the same as those used in the DOCSIS specification.

[0062] The Local Scheduler receives bandwidth requests, queues them and decides on the order in which they are granted so that the minimal reserved rates of each user be satisfied. This may be implemented using one of the published fair queuing algorithms. For example, *Network Delay Analysis Of A Class Of Fair Queuing Algorithms,* by S. J. Golestani, IEEE Journal on Selected Areas of Communications, vol 13, no. 6, August 1995, p 1057-1070; *Rate-Proportional Servers: A Design Methodology For Fair Queuing Algorithms,* by D. Stiliadis and A. Varma, IEEE/ACM Transactions on Networking, April 1998; and *Efficient Fair-Queuing Algorithms For Packet-Switched Networks,* by D. Stiliadis and A. Varma, IEEE/ACM Transactions on Networking, April 1998.

[0063] The Local Scheduler also invokes the Token Bucket Mechanism which can allow or disallow a grant. If a grant is to be given, the Local Scheduler **620** puts it into the Local Time Window **410**.

[0064] The Time Line utilized in the process is preferably a virtual timeline. The measurement unit is a minislot. The Time Line represents bandwidth allocation from a time point called Start Time **415**. An allocation may be a preventive one. This means that it is possible to modify it later. For example, a potential grant given by a Best Effort service may be turned into an actual grant later. Another example of a later modification to a Best Effort grant is shifting a grant in correspondence with its jitter specification.

[0065] Referring now to **FIG. 4**, a Time Line **400** is divided into two areas—a Local Time Window **410** and a Global Time Area **450**. A Local Boundary **425** is the separating point between the Local Time Window and Global Time Area. The Local Time Window **410** is an area from a Start Time **415** till the Local Boundary **425**, while the Global Time Area **450** is from Local Boundary **425** and into infinity.

[0066] In one embodiment, two ways are utilized for placing data grants into the Time Line: (1) Global Periodic Allocation; and (2) Local Allocation. Global Periodic Allocation marks the whole Time Line, including the Global Area, while Local Allocation marks only the Local Time Window. Global Periodic Allocation is invoked by the Global Scheduler, when the scheduler is admitting the Unsolicited Grant Service or when admitting Minimal reserved rate for the Best Effort service. It is also used for providing periodic ranging request opportunities to the wireless modems. Local Allocation is used by the Local Scheduler for processing bandwidth requests.

[0067] Referring again to **FIG. 4**, the Local Time Window **410** is preferably an array of Time Line Elements (**410**$_1$, . . . **410**n), while the Global Time Area **450** is preferably a table of periodic triplets, however, the table may be empty.

[0068] As used herein the term triplets is preferred to mean that a Triplet (i, n, k) is interpreted as a periodic filling of the infinite Time Line tail, as follows: in each sequential portion of n minislots a group of k minislots starting from i is reserved.

[0069] Referring again to **FIG. 3**, Triplet **(5, 100, 10)** would means the allocation of the Global Area of the Time Line as depicted therein. For example, as shown in **FIG. 3**, every set of 100 minislots (A,B,C, . . . etc), 10 minislots are allocated (note dark areas on time line) starting with the 5th minoslot (**A5, B5, C5** . . . etc) in each set.

[0070] Global Periodic Allocation orders triplets on the Time Line by specifying only two of the parameters, n and k. A Triplet Distribution algorithm is used to generate component i of the triplet. The Triplet Distribution algorithm, described with respect to **FIG. 3**, distributes triplets in order to avoid excessive holes. For example, in **FIG. 3**, the triplets are allocated in every set of 100 (e.g., A, B, or C . . .), starting with the 5th available slot (e.g.,

[0071] The size of the Local Time Window **410** is determined by the value of the Local Boundary **425**. A pointer to the Time Line that informs the Local Scheduler of the appropriate distance for Local Grant Allocation. The Local Scheduler does not place an actual grant into the Time Line for a time that is greater than a Grant Boundary **460**. Note, that the Grant Boundary **460** should be no less than the Local Boundary.

[0072] The Local Time Window **410** is updated every time the Map Scheduler moves the Start Time Pointer. The grants allocated by periodic triplets are inserted into the array of Time Line Elements filling up the Local Time Window **410** till the Local Boundary **425**.

[0073] The Grant Time Table is a supplementary structure that gives a compressed representation of the Time Line. It is used by the Map Scheduler **610** for fast insertions of "pending" into Map Messages. The Grant Time Table contains a list of links to data grants in the Time Line, the list is sorted by time.

[0074] The Hole List is a list of "holes", e.g. ungranted minislots. It is used by the Local Grant Allocation algorithm. The Hole List may be sorted by size, allowing for fast finding of holes for allocations.

[0075] The following table provides functions that are preferably used with a Time Line API Interface according to the present invention:

Get	Get an element of the Time Line.
Put	Put an element into the Time Line.
GetPortion	Get a number of elements in a time interval. Used by Map Scheduler
BeginSession	Close access to the Time Line till EndSession. Used for synchronization.
EndSession	Open access to the Time Line. Used for synchronization.
PutPeriodicAlocation	Place a triplet into the Global Time Area.
GetPeriodicAlocation	Get a triplet from the Global Time Area.

[0076] Preferably they are external, to the scheduler functions and applications, APIs that used by the external components and are used at low level implementations. These may for example exist in portions of the network management system. The following external and low level APIs are preferably for resource driven and inner usage.

[0077] Outside APIs

[0078] 1. AllocateRequestPortion

[0079] Functionality:

[0080] Allocates the portion of requests (with the same Acktime) in Time Line;

[0081] Guarantees that all the requests in portion are processed (Map Scheduler is able to call GetMapPortion to prepare the Map for sending)

[0082] Keeps the given temp of request processing.

[0083] 2. GetMapPortion

[0084] Parameters:

[0085] PortionSize—desirable portion size in minislots

[0086] ElemAmount—maximal amount of elements in portion.

[0087] Functionality:

[0088] Cut out the portion of elements from Time Line and provides the portion for Map Scheduler preparation.;

[0089] Moves the Local Time Window (changes StartTime pointer and fills the Local Time Window using the Global Area).

[0090] More detail:

[0091] Reduces the portion in case of last grant cutting or inconsistency of the parameters.

[0092] Removes the last gap according to jitter.

[0093] Restores reservation for time line not included to portion.

[0094] Low Level APIs

[0095] 1. LocalReservAllocation(Grant)

[0096] Parameter: Grant structure (SID, Grant Size, Jitter, Actual/Potential)

[0097] Functionality:

[0098] Looking for a location in Time Line for a given grant.

[0099] Uses a correspondent reserved area while a reservation is done for a given SID.

[0100] If the reserved area is not found or the size is overflow the reserved area, the grand would be allocated by nonreserved local allocation mechanism.

[0101] Uses jitter to move the allocated grant as early as possible.

[0102] 2. LocalAllocation (Grant)

[0103] Parameter: Grant structure (SID, Grant Size, Jitter, Actual/Potential)

[0104] Functionality:

[0105] Looking for a location in Time Line for a given grant.

[0106] Uses a reserved area while corresponding request is not present.

[0107] Provides the holes collection in according to allocated grant jitters.

[0108] 3. RestoreReservation ()

[0109] Functionality:

[0110] Restores freed reserved areas.

[0111] In case of grant allocation on the reserved area place, de-allocates of the grant and put it to the queue for further hot allocation.

[0112] Provides allocation for de-allocated grants.

[0113] The following description of an embodiment of a token bucket mechanism according to the present. For each SID that has ordered a best effort service, the Local Scheduler keeps at least the following information:

R	Maximum sustained traffic rate (service parameter)
B	Maximum traffic burst (service parameter)

-continued

TokenTime	The last time (in minislots) when the token amount was calculated
TokenSize	The amount of tokens(in minislots) accumulated till moment TokenTime

[0114] The Local Scheduler preferably performs as follows:

[0115] When Best Effort service is ordered TokenSize is set to zero.

[0116] When, at moment AckTime, a modem requests a grant of N minislots.

[0117] TokenSize is updated, for example, as follows:

```
TokenSize=min(TokenSize+R*(AckTime-Token-
Time), B).
```

[0118] Data grant, for example, is provided by the rule:

```
if( N < TokenSize) {
                    Grant is given;
                    TokenSize = TokenSize - N;
}
else
    Grant is not given; //request discarded
```

[0119] The present invention may be conveniently implemented using a conventional general purpose or a specialized digital computer or microprocessor programmed according to the teachings of the present disclosure, as will be apparent to those skilled in the computer art.

[0120] Appropriate software coding can readily be prepared by skilled programmers based on the teachings of the present disclosure, as will be apparent to those skilled in the software art. The invention may also be implemented by the preparation of application specific integrated circuits or by interconnecting an appropriate network of conventional component circuits, as will be readily apparent to those skilled in the art.

[0121] The present invention includes a computer program product which is a storage medium (media) having instructions stored thereon/in which can be used to control, or cause, a computer to perform any of the processes of the present invention. The storage medium can include, but is not limited to, any type of disk including floppy disks, mini disks (MD's), optical discs, DVD, CD-ROMS, micro-drive, and magneto-optical disks, ROMs, RAMs, EPROMs, EEPROMs, DRAMs, VRAMs, flash memory devices (including flash cards), magnetic or optical cards, nanosystems (including molecular memory ICs), RAID devices, remote data storage/archive/warehousing, or any type of media or device suitable for storing instructions and/or data.

[0122] Stored on any one of the computer readable medium (media), the present invention includes software for controlling both the hardware of the general purpose/specialized computer or microprocessor, and for enabling the computer or microprocessor to interact with a human user or other mechanism utilizing the results of the present invention. Such software may include, but is not limited to, device drivers, operating systems, and user applications. Ultimately, such computer readable media further includes software for performing the present invention, as described above.

[0123] Included in the programming (software) of the general/specialized computer or microprocessor are software modules for implementing the teachings of the present invention, including, but not limited to, accepting services from client devices (modems), building a timeline, granting periodic allocations in a global part of the timeline, granting bandwidth requests in a local time window and global part of said timeline, building MAP messages based on time grants in the timeline, sending the MAP message to the various client devices (modems), and the display, storage, or communication of results according to the processes of the present invention.

[0124] Obviously, numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described herein.

What is claimed and desired to be secured by letters patent of the United States is:

1. A dynamic quality of service maintenance system for use in a broadband wireless access system comprising a plurality of wireless modems and a wireless hub, the scheduler maintaining adequate bandwidth for the wireless modems based upon the services provided to the wireless modems by the broad band wireless access system, comprising a map scheduler; local scheduler; global Scheduler; admission decision maker; and policy and statistics manager.

2. A wireless communication system, comprising:

a wireless hub configured to send downstream communications on at least one downstream channel and receive upstream communications from at least one client device on at least one upstream channel;

wherein said wireless hub comprises,

a timeline, having timed storage allocations for scheduled services to be provided in conjunction with at least one client device that is communicating with said wireless hub;

a scheduling mechanism configured to,

receive service requests from said client devices,

determine available time for provision of the requested service, and

place a marker identifying the requesting client and the service to be provided in a timed storage location of said timeline corresponding to the available time; and

a map scheduler configured to retrieve markers in a time window of said timeline and build a MAP message that describes time interval allocation on an upstream channel for said time window.

3. The wireless communication system according to claim 2, wherein said wireless communication system is a broadband wireless access system.

4. The wireless communication system according to claim 2, wherein said client devices are Wireless Modem Units.

5. The wireless communication system according to claim 2, wherein said timeline is a data structure having a set of timeline elements including STATION ID, identifying a requesting client, GRANT SIZE, identifying an amount of time allocated to a corresponding STATION ID, JITTER, identifying an amount of jitter associated with the corresponding station ID, and Actual/Potential, identifying whether the timeline element is an actual time grant or a potential element based on potential use of a subscribed service.

6. The wireless communication system according to claim 5, wherein said potential use of a subscribed service is a minimal Reserved Rate in the frame of a Best Effort service.

7. The wireless communication system according to claim 2, wherein said wireless hub further comprises an admission device that accepts and approves services ordered by said client devices.

8. The wireless device according to claim 7, wherein said services ordered include minimal reserved frame rates in a best effort type service.

9. The wireless device according to claim 7, wherein said scheduler comprises,

a global scheduler configured to make allocations in said time line for preliminary global time scheduling for SIDs according to the admitted Services by marking the Time Line with periodic potential or actual Time Line Elements (grants), and

a local scheduler configured to process incoming bandwidth requests and generate data grants in accordance with a service, registered for the requesting client.

10. The wireless device according to claim 2, wherein said scheduler comprises,

a global scheduler configured to make allocations in said time line for preliminary global time scheduling for SIDs according to the admitted Services by marking the Time Line with periodic potential or actual Time Line Elements (grants), and

a local scheduler configured to process incoming bandwidth requests and generate data grants in accordance with a service, registered for the requesting client.

11. The wireless device according to claim 10, wherein said timeline comprises,

a local window comprising an array of time line elements, and

a global window comprising a table of periodic triplets;

said local scheduler is further configured to search for holes in said array of time line elements and assign said bandwidth requests to said holes.

12. The wireless device according to claim 11, wherein:

said local scheduler includes a hole list comprising a list, sorted by size, of unallocated contiguous mini-slots; and

said search comprises matching a BW request to said hole list.

13. The wireless device according to claim 11, wherein said global scheduler assigns said grants in a table of periodic triplets, including, i, n, k, in which each group of n mini-slots, starting from the i^{th} mini-slot, a group of k mini-slots is assigned.

14. The wireless device according to claim 2, wherein said scheduler includes a model configured to determine time grants needed for supported services.

15. The wireless device according to claim 2, further comprising:

a timeline API configured to set and retrieve time storage allocations to/from said timeline.

16. The wireless device according to claim 15, wherein:

said timeline further comprises a local window comprising an array of time line elements, and

a global window comprising a table of periodic triplets; and

said timeline API includes functions for at least one of Get, configured to get an element of the timeline, Put, configured to put an element on the timeline, GetPortion, configured to get a number of elements in a time interval, BeginSession, configured to close access to the timeline until and end of a session, EndSession, configured to open access to the timeline, PutPeriodicAllocation, configured to place a triplet into the global time area, and GetPeriodicAllocation, configured to get a triplet from the global time area.

17. A method of service scheduling of an upstream channel in a point to multi-point communication system, wherein said point is a hub device, and said multi-point is a set of client devices communicating with said hub, comprising the steps of:

scheduling said services in a timeline so as to identify a client device;

building a MAP message comprising at least a portion of the services scheduled in said timeline; and

communicating said timeline to said client devices.

18. The method according to claim 17, wherein:

said step of scheduling comprises the steps of,

scheduling periodic grants across an entire length of said timeline; and

scheduling bandwidth requests from said clients in a local time window of said timeline;

wherein said local time window is a portion of said timeline to be allocated in a next MAP message(s) communicated in said communicating step.

19. The method according to claim 18, further comprising the step of modeling admitted services and making grants in said timeline based on said modeling.

20. The method according to claim 17, wherein said step of building a MAP message comprises the steps of:

closing a buffer for incoming bandwidth requests at a predetermined time interval;

extracting a portion of elements from the timeline;

shifting a start time pointer indicating a start of a local time window on said timeline for bandwidth request allocations; and

constructing said MAP message.

21. A device for determining time grants for at least one shared communication line, comprising:

means for storing time grants;

means for placing periodic time allocations in said storing means for services admitted to devices using said shared communication line; and

means for placing bandwidth requests into said storing means for bandwidth requested by said devices;

means for building a message indicating which clients may access said at least one shared communication line during specified time intervals; and

means for communicating said message to said clients.

22. The device according to claim 20, wherein said at least one shared communication line is a broadband wireless communication channel.

23. The device according to claim 20, wherein said clients are a set of wireless modems in a point to multi-point broadband wireless system.

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